Validation and Verification of Operational Land Analysis Activities at the Air Force Weather Agency

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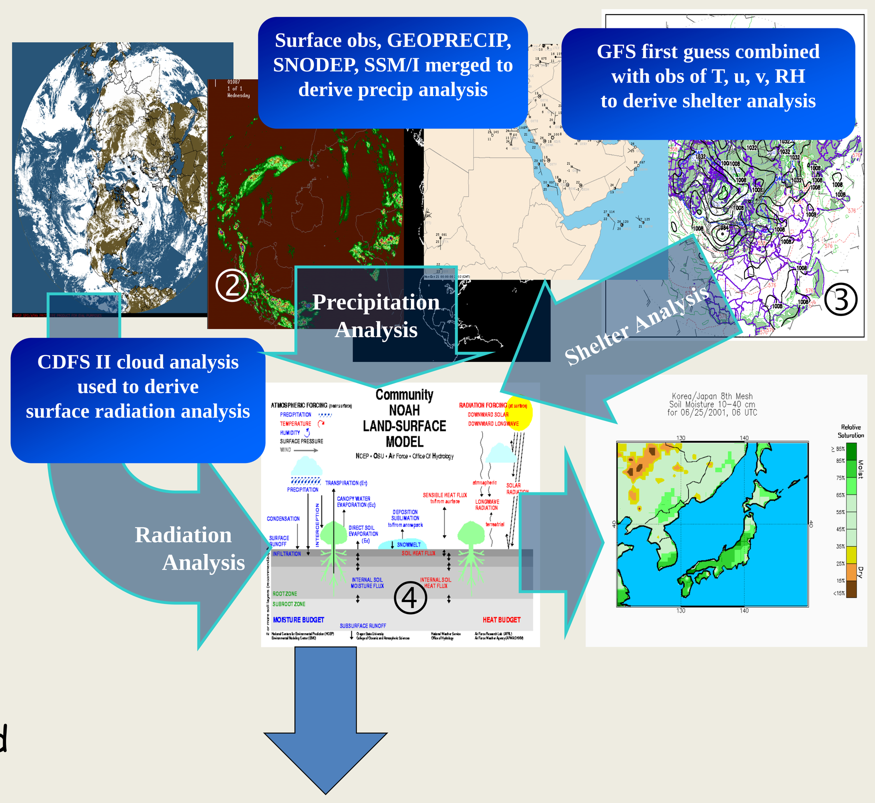
Introduction

The NASA developed Land Information System (LIS) is the Air Force Weather Agency's (AFWA) operational Land Data Assimilation System (LDAS) combining real time precipitation observations and analyses, global forecast model data, vegetation, terrain, and soil parameters with the community Noah land surface model, along with other hydrology module options, to generate profile analyses of global soil moisture, soil temperature, and other important land surface characteristics.

- A range of satellite data products and surface observations used to generate the land analysis products
- Global, ¼ deg spatial resolution
- Model analysis generated at 3 hours

The operational land analysis users include:

- USDA Foreign Agriculture Service
- AFWA Dust Transport Algorithm
- AFWA Weather forecast model (WRF)
- ARL White Sand Missile Range
- AFWA CDFSII world wide merged cloud analysis
- Naval Research Laboratory
- AF Technology Application Center
- Other modeling centers (NCEP, NWS offices)



Soil moisture
Soil temperature
Surface fluxes (latent and sensible heat)
Evapotranspiration
Snowcover
Snow water equivalent (SWE)
Snow depth
Runoff

AFWA recognizes the importance of operational benchmarking and uncertainty characterization for land surface modeling and is developing standard methods, software, and metrics to verify and/or validate LIS output products. To facilitate this and other needs for land analysis activities at AFWA, the **Model Evaluation Toolkit (MET)** – a joint product of the National Center for Atmospheric Research Developmental Testbed Center (NCAR DTC), AFWA, and the user community – and the **Land surface Verification Toolkit (LVT)** – developed at the Goddard Space Flight Center (GSFC) – have been adapted to operational benchmarking needs of AFWA's land characterization activities.

Example 1: Precipitation

Verification Setup

Precipitation Products Analyzed:
1. AFWA GEOPRECIP: Geostationary IR technique from Vicente et al. (1998)
2. Bias-corrected CMORPH based on Joyce et al. (2004)
3. GFS Forecasts: NOAA

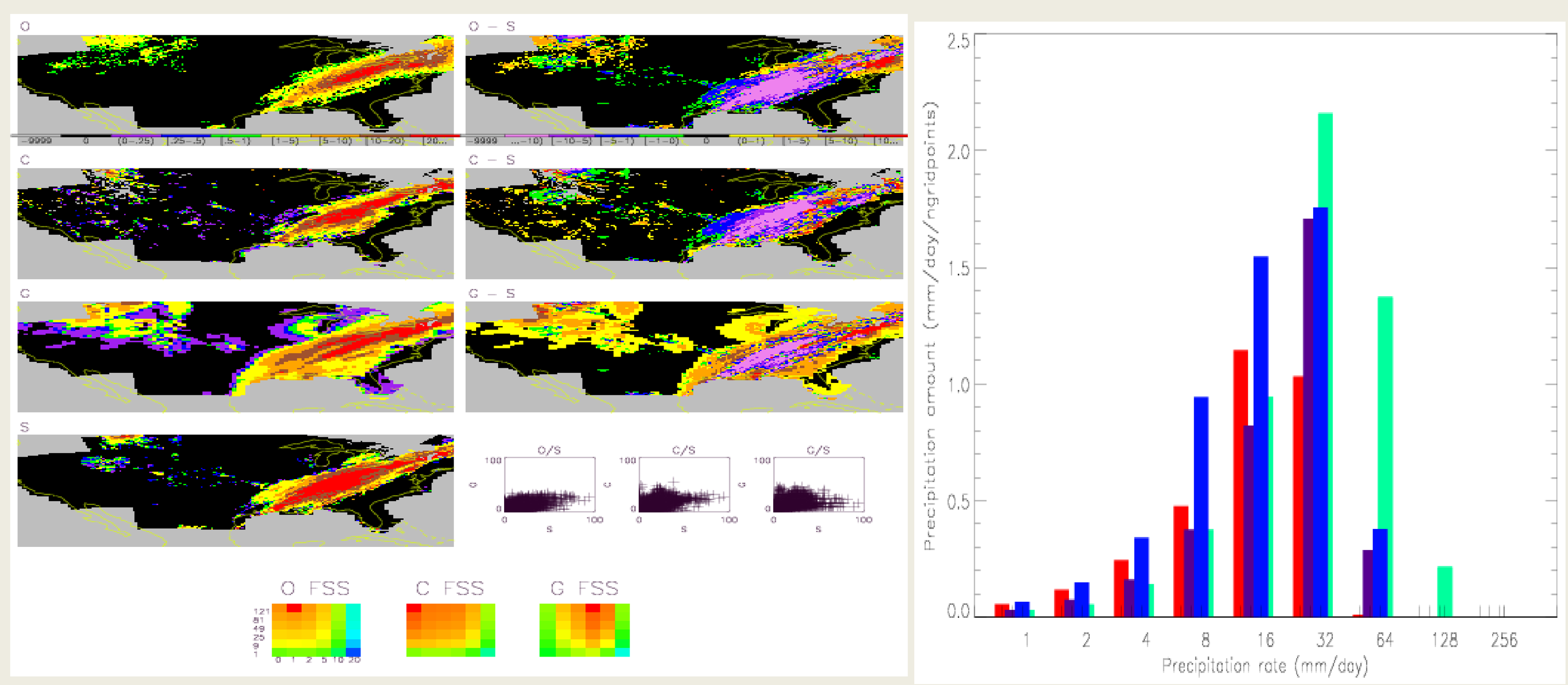
Reference Data: NOAA Stage IV analysis (http://www.emc.ncep.noaa.gov/mmb/ylin/pcpanl/stage4/)

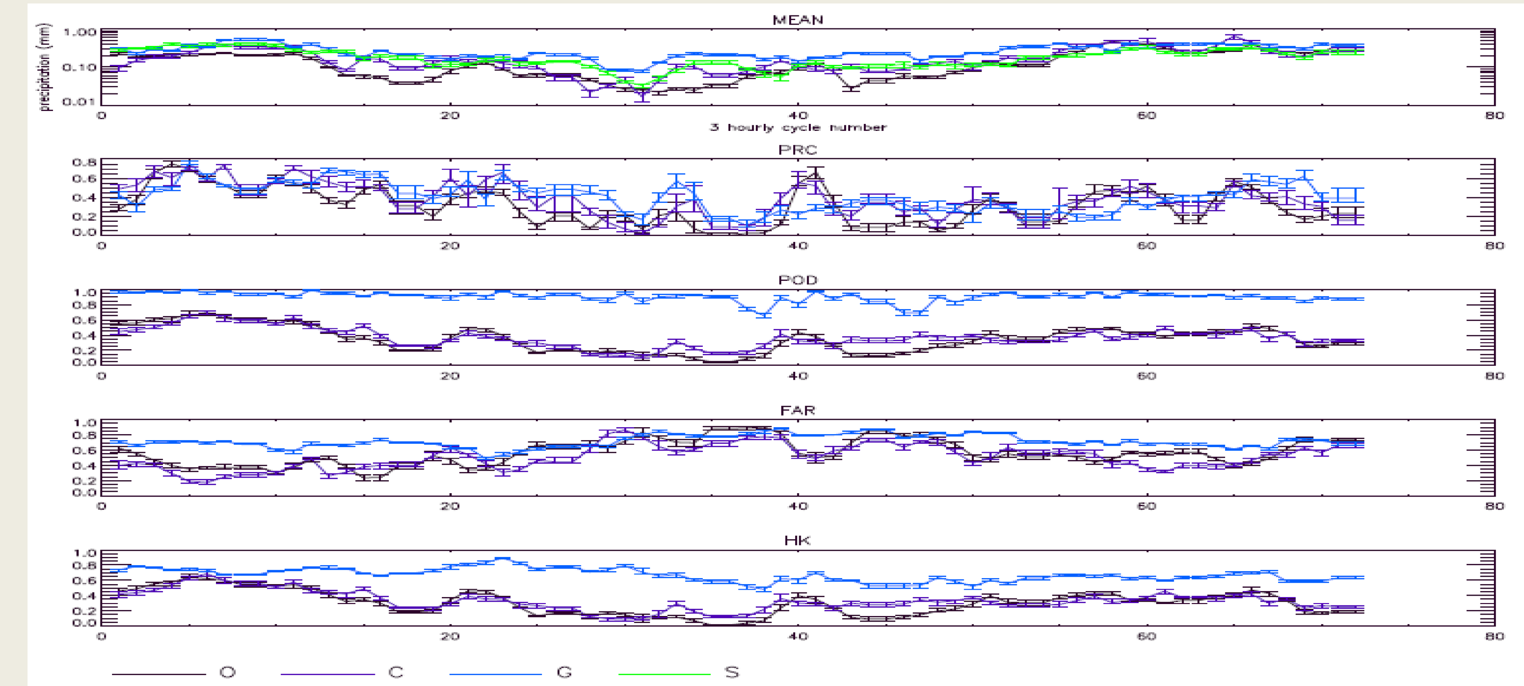
Time Period: May 3, 2011 to May 11, 2011

Location: CONUS

Analysis Tool: MET (http://www.dtcenter.org/met/users/)

Results





Case (plot color)	O (+/|)	C (+)	G (+)	Stage IV (+)
Description	AFWA GEOPRECIP	AFWA CMORPH	GFS forecast	NCEP radar/gauge analysis
Native resolution	64th mesh projected to 0.1°	~0.08°	0.5°	~0.04°
Interpolation	Bilin. to 0.1; neighb. to 0.25	Neighb. to 0.25	Bilin. to 0.08, neighb. to 0.25	Bilin. to 0.25
Accumulation	3 hour	1/2 hour accumulated to 3 hour	3 hour	1 hourly accumulated to 3 hour
Bias from mean (MEAN)		x		N/A
Pearson correlation (PRC)		x		N/A
Prob. of detection (POD)			x	N/A
False alarm *ratio* (FAR)		x		N/A
Hanssen Kuiper (HK)			x	N/A
Fractional Skill Score (FSS)		x		N/A
Distribution		x		N/A

Precipitation Verification Summary

- "Best" product as would be judged for a particular application – i.e. precipitation product processed for forcing of LIS at AFWA - per each metric and details of each "case" summarized above.
- For this isolated case, CMORPH performs best in terms of bias, PRC, FSS, and distribution, while GFS performs best for POD and HK. This analysis must be conducted for many cases/regimes before definitive conclusions can be drawn, while it is recognized that even isolated cases such as this can be important to users of such products
- This study also indicated that, during such times, CMORPH would further benefit from a more "real time" gauge analysis bias correction scheme than the more climatological correction scheme used in what is seen here.
- Metrics are all sensitive to resolution (native and interpolated), projection to common grid, precipitation intensity, threshold, and accumulation period, while sometimes swapping relative "goodness", of course, depending upon which combination of these is deemed most important.

Example 2: Shortwave radiation

Verification Setup

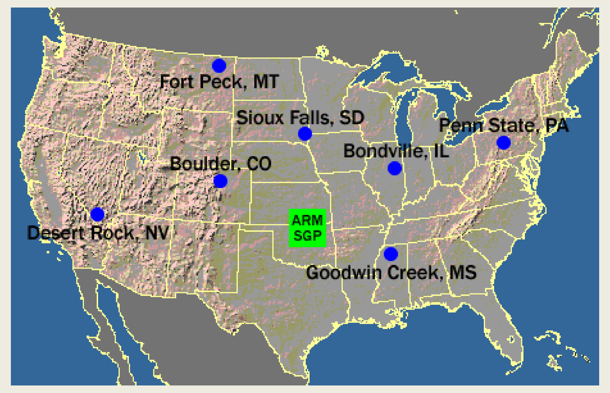
AGRMET shortwave radiation

Reference Data: SURFRAD (http://www.srrb.noaa.gov/surfrad/)

Time Period: Jan 1, 2006 to 1, Jan 2007

Location: CONUS

Analysis Tool: LVT (Kumar et al. (2011))



Results

	RMSE (W/m2)	Bias (W/m2)	R
Desert Rock	78.5	-12.8	0.97
Boulder	102.0	19.9	0.94
Fort Peck	95.0	33.8	0.94
Sioux Falls	86.1	15.1	0.94
Bondville	89.0	6.48	0.94
Penn State	78.3	10.7	0.95
Goodwin creek	84.3	13.5	0.95

Verification Summary:

- The evaluation across the SURFRAD stations indicate good performance of the AGRMET product (high correlations, low biases)
- The variability in skill scores across the domain is low, indicating consistent performance of the radiation product.

Example 3: Soil Moisture

Verification Setup

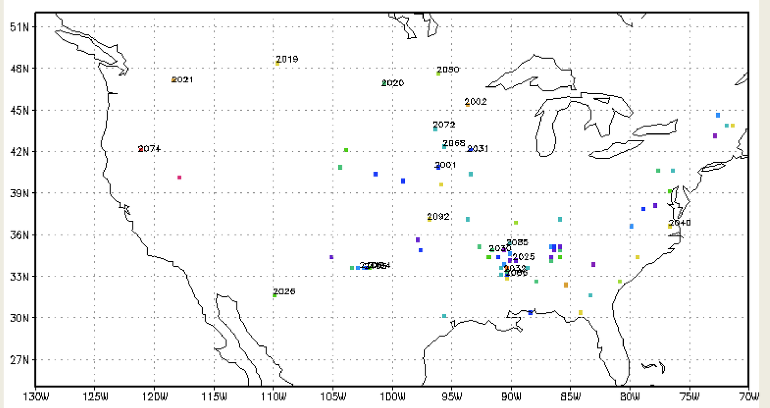
Soil Moisture Products Analyzed:
1. 10 cm volumetric soil moisture (Layer 1) output from LIS/Noah2.7.1 with AGRMET forcing,

Reference Data: SCAN (http://www.wcc.nrcs.usda.gov/scan/)

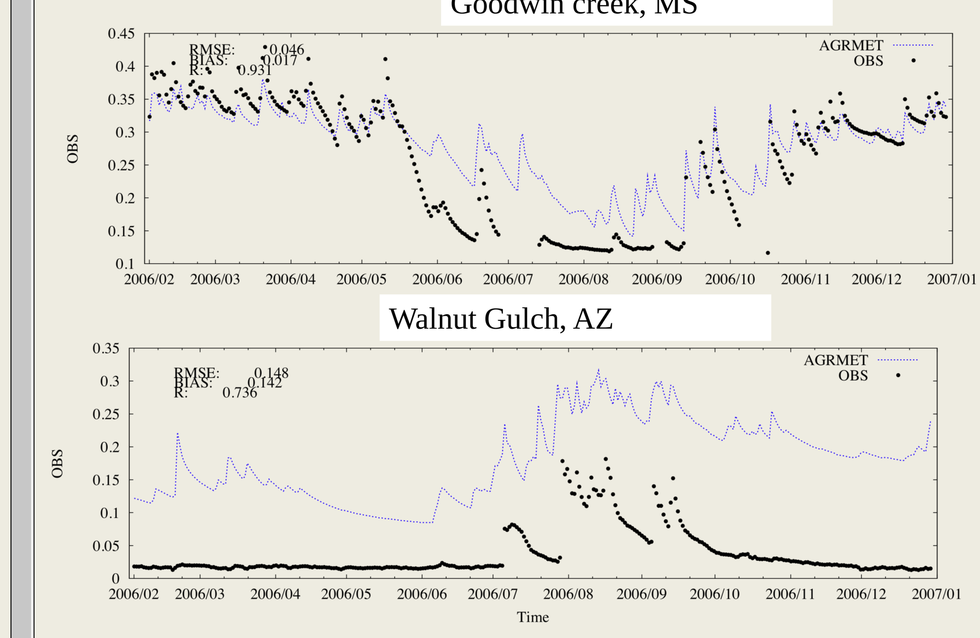
Time Period: Jan 1, 2006 to 1, Jan 2007

Location: CONUS

Analysis Tool: LVT (Kumar et al. (2011))



Results



Domain Averaged statistics across selected SCAN stations	
Bias (volumetric)	0.0788
RMSE (volumetric)	0.120
R	0.65

Verification Summary:

- Wide range of metrics' values over different hydrologic regimes.
- Points and areas/grids are not expected to be representative, so other metrics in LVT such as the anomaly correlation statistic are more appropriate.

Example 3: Surface Fluxes

Verification Setup

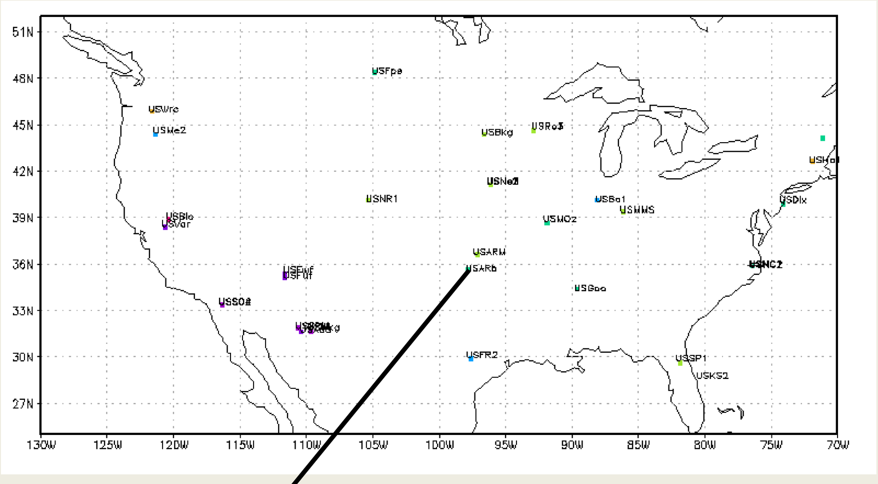
Products Analyzed:
1. Latent and Sensible heat flux output from LIS/Noah2.7.1 with AGRMET forcing,

Reference Data: Ameriflux (http://public.ornl.gov/ameriflux/)

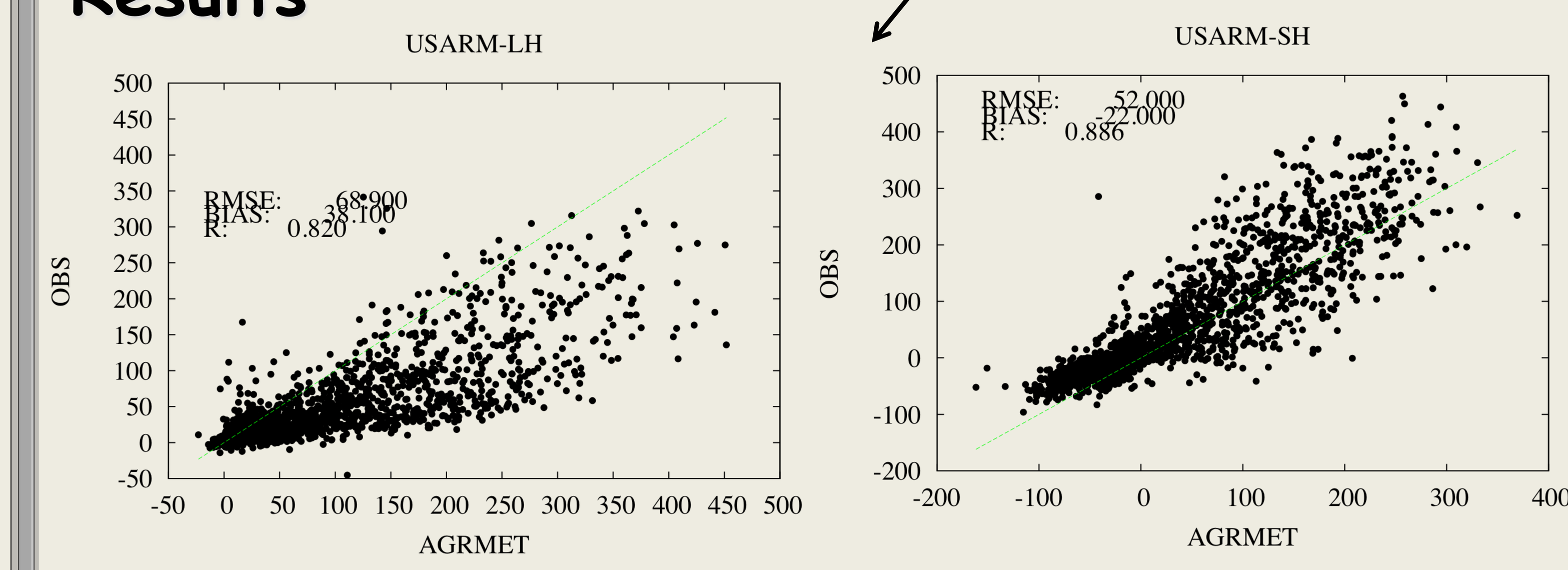
Time Period: Jan 1, 2006 to 1, Jan 2007

Location: CONUS

Analysis Tool: LVT (Kumar et al. (2011))



Results



Domain Averaged statistics across selected Ameriflux stations		
	Latent Heat flux (LH)	Sensible Heat flux (SH)
Bias (W/m2)	15.7	-11.4
RMSE (W/m2)	51.4	60.8
R	0.80	0.82

Verification Summary:

- Evaluation indicates a systematic underestimation of sensible heat fluxes and a systematic overestimation in latent heat fluxes
- Significant variability in skill scores across the stations are observed.

Summary

- Evaluation tools have been adapted, and continue to be adapted, at AFWA for validation and verification of land surface characterization efforts.
- The use of formal benchmarking tools enable the systematic quantification and evaluation of enhancements made to the operational environment.
- The availability of performance benchmarks provide quantified measures of accuracy and uncertainty to the end-users of the products.

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